An example of such a project is the Mary Rhodes Pipeline constructed by the City of Corpus Christi and the Nueces River Authority in 1997 and 1998. This pipeline brings a minimum of 41,840 acft/yr of water from Lake Texana, located in the distant Lavaca River Basin, and delivers it directly to the O.N. Stevens Water Treatment Plant thereby reducing demand on the CCR/LCC System. The primary benefit of this pipeline is the additional water supply provided, but the project has a secondary benefit of increasing freshwater inflows to the Nueces Estuary. The last illustration in Figure 5-3 shows that this new water supply project has benefited the Nueces Estuary by creating additional opportunities for enhanced freshwater inflows. For example median annual inflows into Nueces Bay increased from 117,000 acft/yr without the pipeline to 152,000 acft/yr with the pipeline, an increase of 35,000 acft/yr, based on an annual demand of 186,630.

5.5.6 Stream Segments

Perennial streams in the Hill Country are fed by numerous springs with the most significant streams including the West Nueces, Nueces, Dry Frio, Frio, Sabinal, Hondo and Verde. Under normal conditions, most of these streams loose their entire baseflow to the Edwards Aquifer recharge zone (except for the Nueces and Sabinal Rivers). A unique feature of the Nueces River is an 81-mile-long segment downstream of Cotulla, Texas, commonly referred to as the "braided reach." (See Figure 5.1D) The braided reach begins about 15 miles downstream of Cotulla, where the single channel of the river transitions to a system of interconnected braided channels. These interconnected channels continue to a location about 12 miles upstream of Simmons, Texas. Studies performed by the U.S. Geological Survey (USGS)[5] indicate that significant streamflow losses occur in this reach.

Listed below are annual streamflow volume statistics measured at the Nueces River where it enters Lake Corpus Christi. The highly variable flows are indicative of the varied hydrologic conditions prevalent in this basin from extreme droughts to hurricane events:

- Average = 631,000 acft/yr
- Median = 421,000 acft/yr
- Maximum = 2,625,200 acft/yr
- Minimum = 56,700 acft/yr

[5] U.S. Geological Survey, "Conveyance Characteristics of the Nueces River, Cotulla to Simmons, Texas," Water-Resources Investigations Report 83-4004, 1983.

5.5.6.1 Hill Country Streams

The headwaters of the Nueces River and its tributaries are found in the Texas Hill Country area of Edwards, Real, Bandera, Kinney, Medina and Uvalde Counties. A terrain with steep slopes and very shallow soils characterize this area. The streams located upstream of the Edwards Aquifer recharge zone are typically perennial streams with significant environmental and recreational benefit. These pristine streams provide essential habitat to many plants, fish and wildlife.

The streams described above are a sharp contrast to the characteristics of these same streams just downstream of the Edwards Aquifer recharge zone. At the downstream boundary of the Edwards Aquifer recharge zone, the streams become either dry or intermittent due to the large channel losses over the recharge zone. The combination of the large flow losses and the semi-arid climate preclude the existence of significant aquatic habitats in many of the downstream reaches.[6] Dry streambeds that only occasionally support aquatic ecosystems are not uncommon in this part of the basin. Table 5-2 below shows how the channel losses and recharge that occurs over the Edwards outcrop dramatically reduces the flows in the four stream segments when recharge enhancement projects are proposed (see section 5.6.3.3) and provide the basis for the fact that these stream segments do not support significant aquatic habitats because they are very often dry.

Table 5-2 Median Streamflow Table[7]

Median Streamflows (Existing) for Four Streams near Downstream edge of Edwards Aquifer Recharge Zone													
Stream	**Flows**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Verde Creek (estimated)	Median Downstream Flows	0	0	0	0	0	0	0	0	0	0	0	0
Hondo Creek (gage)	Median Downstream Flows	0	0	0	0	2	0	0	0	0	0	0	0
Sabinal River (gage)	Median Downstream Flows	45	25	22	9	35	0	0	0	44	125	82	57
Frio River (gage)	Median Downstream Flows	0	0	0	0	0	0	0	0	0	0	0	0

[6] Paul Price Associates, Inc., "Environmental Assessment for Four Edwards Aquifer Recharge Enhancement Projects in the Upper Nueces River Basin." Nueces River Authority and San Antonio Water System, October 2000.
[7] Ibid.

5.5.7 Nueces River Delta and Estuary

Composing a complex array of channels, pools, marshes and tidal flats, the Nueces River Delta is one of the most extensive marsh ecosystems on the Texas Gulf Coast and an integral part of the Nueces Estuary. The delta provides a critical transitional environment used by marine and estuarine species at important stages of their life cycle. The Nueces Delta is approximately 20,000 acres in size and home to numerous fowl, aquatic, estuarine and wildlife species (Figure 5-4). Some of these species are shown in Figure 5-5 and include: Sea ox-eye daisy, Glasswort, Salt-wort, Sea-blite, Coastal dropseed, Several Migratory Bird Species and many other plant and animal species. Many commercial fishing species that are routinely harvested from the Nueces Estuary use the delta as breeding and/or feeding grounds; these species include Red Drum, Black Drum, Brown Shrimp, White Shrimp, Blue Crab, Atlantic Flounder and Speckled Trout.

The economic impact of the harvest of these species to the state is important. The estimated value of the Nueces Estuary (as determined by the Corpus Christi Bay National Estuary Program) is approximately $814 million per year to the state's economy.[8] This annual return is based on naturally renewable resources, which are free for the harvest or use and do not have to be subsidized. Measures do need to be taken to be protected these resources from destruction and poor management practices. Texas coastal environments contribute multi-billion dollar inputs to the state's economy through a navigation network of national importance, a vast resource for minerals, seafood and recreation and serving as a natural source of natural waste treatment for many nutritive materials and other by-products of our society. New collective solutions for water problems are needed in several areas of Texas but few are as complex, and none involve more public lands, waters and wildlife than do the bays and estuaries.

[8] Powell, Gary, Texas Water Development Board, Phone Conversation, August 2002.

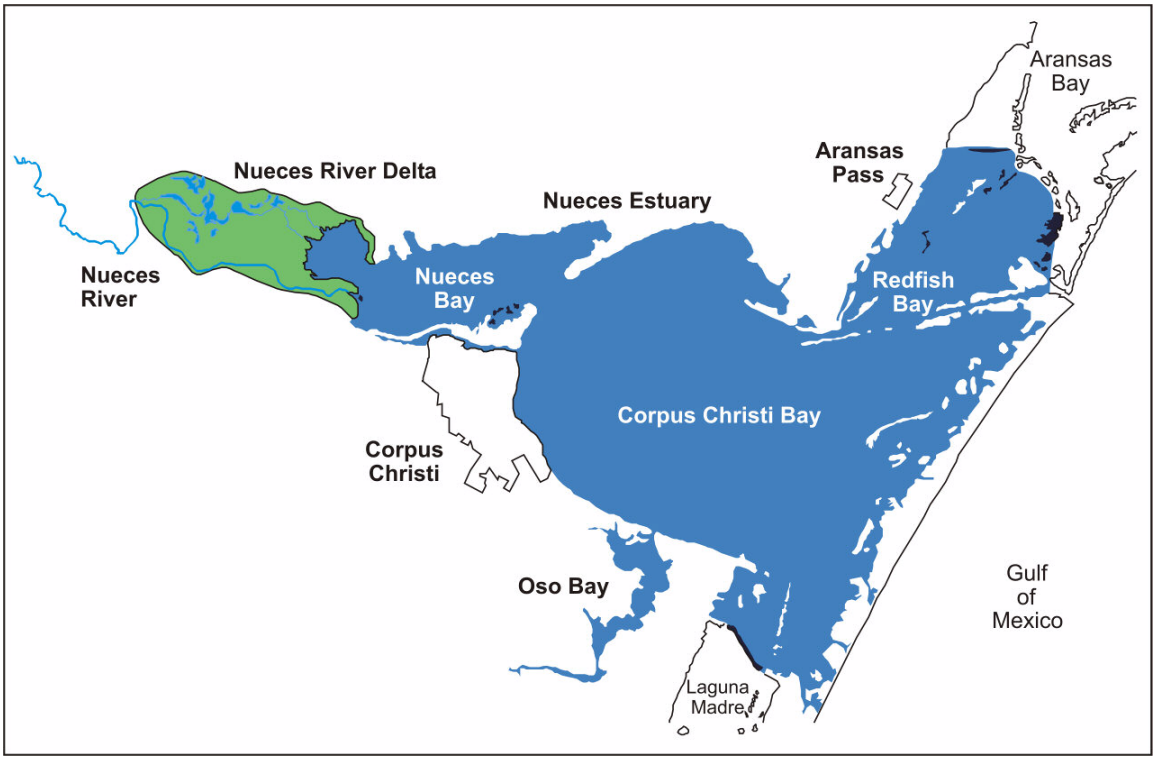

Figure 5-4. Nueces Delta and Estuary

Figure 5-5 Common Species Associated with the Nueces Estuary

A normal estuary is regularly inundated with salt water from tidal flow and freshwater from over-flows from the river. These freshwater inflows are important in maintaining the critical balance of salinity needed in the estuary for a healthy environment. Specifically, the freshwater facilitates nutrient exchange and the buffering of the bay salinity. However, with the combined effects of the construction of the enlargement of Lake Corpus Christi in 1958 and the construction of Choke Canyon Reservoir in 1982, and with each drought cycle producing less inflows (Figure 5-6), freshwater inflow to the delta has been greatly reduced. This activity has reduced the number and volume of flood events that reach the Nueces Estuary and provide this critical habitat with fresh water. The average number of flood events per year has been reduced

from 2.3 before the construction of the reservoirs to only 0.8 since the completion of Choke Canyon Reservoir in 1982. Likewise, the volume of water that reaches the delta has been reduced from over 9,000 acft/yr before the construction of the reservoirs to only 600 acft/yr since the completion of Choke Canyon Reservoir.[9] As the freshwater inflows diminish, the estuary's function as a healthy productive biological ecosystem has been significantly reduced. Consequently, this has led to a hypersaline, or "reverse estuary" condition where salinity values in the delta are generally higher than that of the bay or ocean. Many species can tolerate these harsher environmental conditions, but the prolonged periods of salinity-induced stress leads to lower biological productivity as well as less species diversity.

The drought of 1954 – 1956 is considered to be the "drought of record" for the State of Texas. What Figure 5-6 shows is that for the Nueces River Basin three droughts that have occurred since the "worst drought of record" are actually more sever in terms of reservoir inflows.

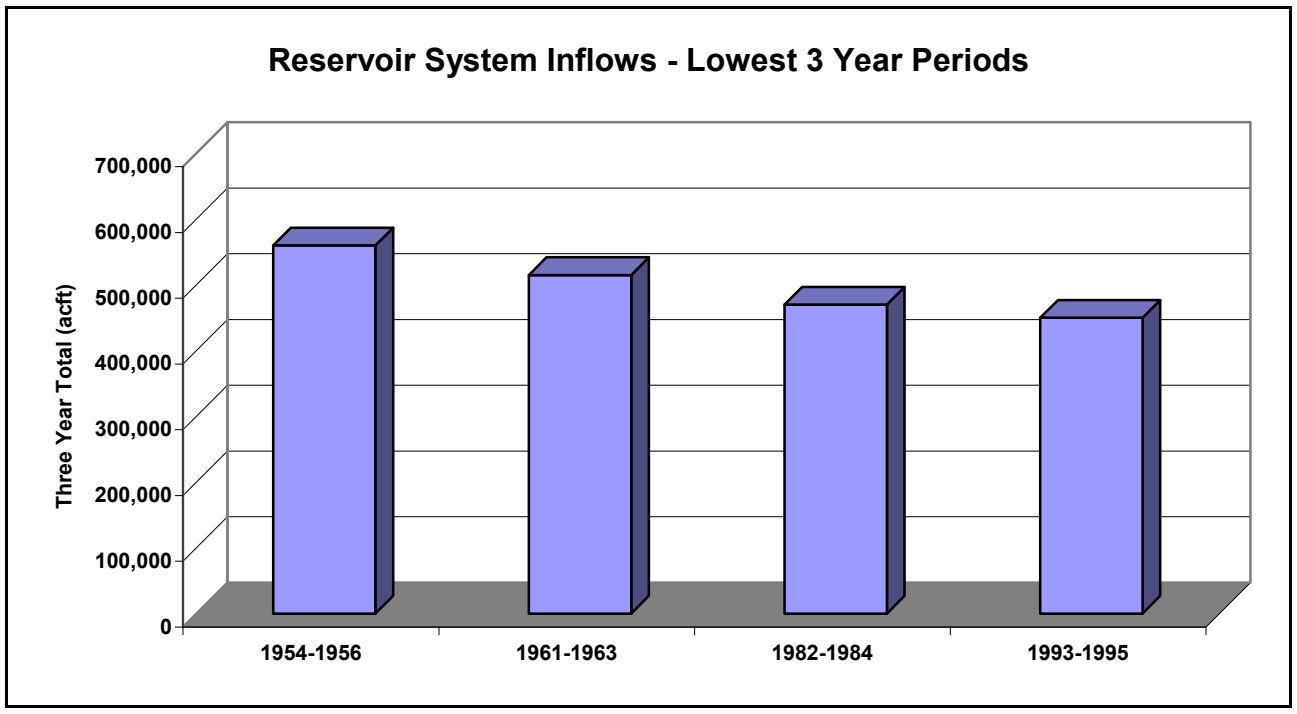

Figure 5-6 Reservoir System Inflows from Last Four Major Droughts

[9] USBR, "Rincon Bayou Demonstration Project," U.S. Department of the Interior, September, 2000. These numbers reference the estimated volume of water that entered the delta as a direct result of the Nueces River overflowing its banks, and not the total inflow into the estuary.

The Nueces Estuary Advisory Council (NEAC) is a technical advisory committee that was created to address concerns about the health of the Nueces Estuary. This council is comprised of people from many different areas of interest and chaired by the Texas Natural Resource Conservation Commission. This council provides a well-rounded opinion on issues concerning the health of the Nueces Estuary. NEAC has identified the following goals and objectives in relation to the Nueces Estuary.

- Preserve the ecological environment and health of related natural resources in the Nueces River Basin and Nueces Estuary.
- Maintain and preserve (protect) a supply of water to meet the demands of identified beneficial uses in the Nueces River Basin and Corpus Christi area.
- Minimize the release of stored waters consistent with the preservation of a healthy Nueces River Basin and Nueces estuarine system.
- Protect the economic interest of all citizens that are dependent upon the Choke Canyon/Lake Corpus Christi reservoir system and the Nueces Estuary.

5.6 Potential Federal Interest Projects

Many individual project alternatives were examined in the preliminary screening process. The resulting opportunities described below represent those projects identified in the basin that had the most merit in terms of Federal interest, local sponsor support, and promise of continuation into the next phase of study, feasibility. Table 5-3 below summarizes the problems identified in the Nueces River Basin that the proposed project alternatives present an opportunity to solve.

Table 5-3 Summary of Problems and Opportunities

Problem	*Opportunity*
The ecosystem of the Nueces River Delta is degrading from a lack of freshwater inflows.	The opportunity exists to restore the ecosystem of the Nueces River Delta with innovative alternatives that provide the opportunity for increased freshwater inflows.
The pumping of the Edwards Aquifer has reduced springflow and streamflow to critical habitats of endangered species.	The opportunity exists to construct recharge enhancement projects in the Nueces River Basin, which will increase springflow and streamflow to the benefit of the endangered species.
The residents along the Nueces River and its tributaries are susceptible to flood damage.	The opportunity exists to study structural and non-structural alternatives to reduce the damages associated with these flooding events.
There are stream segments in the Nueces River Basin that are suffering from the effects of adverse human activity as well as from exotic aquatic plants that are destroying natural ecosystems.	The opportunity exists for ecosystem restoration in affected stream segments to return them to a more natural state.
The Nueces Basin is suffering from worsening droughts and water shortages.	The opportunity exists to develop innovative multipurpose projects that provide flood damage reduction and/or ecosystem restoration as well as water supply benefits.

5.6.1 Flood Damage Reduction

The unique hydrologic characteristics of the Nueces River Basin create opportunities for localized, sometimes widespread, flooding. The steep slopes and shallow soil characteristics in the Hill Country provide conditions for one of the most treacherous areas in the nation for flash flooding. In contrast, the lower basin, which has flat slopes, is prone to flooding from hurricanes, tropical storms and large upstream storm events. Most of the damages from the flooding that does occur usually take the form of overtopped roads, and residential and small structure flooding. Potential flood damage reduction projects identified in the Nueces River Basin have been identified with the assistance of the local sponsors.

5.6.1.1 July 2002 Flooding in the Nueces River Basin

During the process of developing this 905(b) analysis study, a major flood event occurred throughout the Nueces River Basin that caused severe flood damage throughout the middle to lower parts of the basin. According to the Corpus Christi Caller Times and the National Weather Service in Corpus Christi, the levels of flooding associated with this storm were second only to the levels of flooding associated with Hurricane Beulah in 1967, making this the second worst

flooding event for the Nueces River in recorded history. During Hurricane Beulah an estimated maximum 128,000 cubic-feet/second (cfs) flowed through the river as measured at Three Rivers compared to a maximum of about 50,000 cfs for this storm event.

Information regarding this flood event is still being compiled; however, some preliminary damage estimates from the Federal Emergency Management Association (FEMA) were available at the time of this report writing. In six of the heaviest hit counties in this region, over 2,000 applications for Federal aid have been received by FEMA. Statewide estimates of flood damages, including property loss, damaged infrastructure, and lost economic opportunity, are in the range of $1 billion. The Nueces River Basin's share of this total is estimated to be around $100 million with an estimated $85 million already earmarked to repair roads, bridges and infrastructure damage. Eight people also lost their lives as a direct result of the flooding. The Nueces River Authority recorded some of the flooding as it occurred in the form of aerial photographs taken from a small plane; some of these photos are included in Figures 5.7, 5.8, 5.9 and 5.10.

Possible alternatives, both structural and non-structural, that could be implemented to mitigate the flood damages associated with this storm event have yet to be identified and studied. However, it is speculated that if Cotulla Reservoir had been in place then it certainly could have served to reduce the peak floodwaters traveling down the Nueces River, reducing some of the impacts endured by the citizens in the area from Three Rivers down to the Nueces Bay. The maximum-recorded average daily flow measured at Cotulla during this storm event was 17,100 cfs. Another possible alternative project that could serve to mitigate flood damages involves the construction of a high volume pump station and an off-channel storage reservoir just above Lake Corpus Christi. Since lag times on flows in the lower basin tend to be long, this would create an opportunity where large capacity facilities to divert water into off-channel storage could reduce the downstream impacts by between 2,000 and 10,000 cfs. Further study, including the development of a basin wide flood model, should be done in the feasibility phase before too much merit is assigned to these or other potential projects.

Figure 5-7 (left to right) CCR Dam Spilling; Inundated State Park at CCR; Tips State Park at Three Rivers

Figure 5-8 Three Photos of the Nueces River North of Lake Corpus Christi

Figure 5-9 (left to right) Saltwater Barrier Dam on Nueces River; LCC at FM 534; Nueces River at IH-37 Looking North

5.6.1.2 Flooding Downstream of Lake Corpus Christi

Description: The area immediately downstream of Lake Corpus Christi is prone to flooding. This generally involves the overtopping and closing of a few roads and leaving some citizens stranded from their homes until the waters recede. Residential and small structure

flooding is also typical of these flooding events. Lake Corpus Christi does not have any flood storage, so there is very little way to mitigate the flooding events coming downstream when Lake Corpus Christi is at capacity (approximately 300,000 acft). Although the citizens that are routinely affected are concerned about the magnitude of large floods, they are concerned more often with the timing, duration, and notification of smaller flood events. The citizens would like some warning that would tell them when the flood will arrive and how high the waters will rise. Future conditions without a flood damage reduction study/project will continue to be the damage and loss of property due to the lack of preparedness of the citizens. The development of a basin-wide flood-forecasting tool would serve to reduce the flooding problems in this area. Additionally if a large capacity off-channel reservoir and pump station could be constructed near Lake Corpus Christi then water could be pumped into this facility allowing for flood storage in Lake Corpus Christi.

Benefits: The benefits from a flood forecasting system that would be able to inform the citizens of the timing and volume of future flood events could allow them to better prepare, remove valuables and evacuate with greater success. Structural and non-structural flood damage reduction projects will also be evaluated in the feasibility phase.

Potential Sponsors: The City of Corpus Christi and possibly the Nueces River Authority are interested sponsors for this project.

Figure 5-10 (left to right) Lake Corpus Christi Dam Looking Downstream; Nueces River Diversion Channel; Nueces River east of IH-37

5.6.2 Ecosystem Restoration

Proposed ecosystem restoration projects include measures to help restore the biological productivity of the Nueces Delta and Estuary system, projects to alleviate damage done to streams in the Upper Nueces River Basin, and construction of recharge enhancement projects in the Nueces River Basin to restore ecosystems in the Nueces, San Antonio and Guadalupe River